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STRATEGIES AND MEASURES TO MITIGATE DROUGHT IMPACTS

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The authors of this paper share their own reflections on drought and drought management. Different aspects such as the development of drought impact matrixes, drought impact assessment and strategies designed to mitigate drought have been discussed here. Direct long term or proactive actions, direct short term or reactive actions and supplementary or indirect actions are also analyzed.

Key words: drought, drought management, drought impacts.

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СТРАТЕГІЇ ТА ЗАХОДИ З ПОПЕРЕДЖЕННЯ ДІЇ ПОСУХИ

В роботі описано форми дії посухи, оцінювання даного впливу, а також стратегії, спрямовані на скорочення розвитку посухи. Аналізуються прямі довгострокові або профілактичні заходи, прямі короткострокові або реактивні заходи, а також додаткові або посередні заходи.

Ключові слова: посуха, система контролю посухи, дія посухи.

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СТРАТЕГИИ И МЕРЫ ПО ПРЕДУПРЕЖДЕНИЮ ВОЗДЕЙСТВИЯ ЗАСУХИ

В настоящей работе описываются формы воздействия засухи, оценивание данного воздействия, а также стратегии, направленные на сокращение развития засухи. Анализируются прямые долгосрочные или профилактические мероприятия, прямые краткосрочного или реактивные мероприятия, а также дополнительные или косвенные мероприятия.

Ключевые слова: засуха, система контролирования засухи, воздействие засухи.

Drought can be defined as a long period of abnormally low rainfall or a prolonged shortage of rainfall, especially one that adversely affects growing or living conditions. Drought is a natural phenomenon with a cyclic behavior more frequent in regions where rainfall is very irregular. However, climate change seems to be responsible for the increase in extreme weather, such as floods and droughts, in other regions.

In this paper, the authors will discuss aspects such as the development of drought impact matrixes, drought impact assessment and strategies designed to mitigate droughts. All droughts raise, namely, "How much damage is inflicted by drought?", "Who is most affected by drought?" and "Where is damage inflicted most?" With this aim, the present document is structured in such a way as to bring to light certain initiatives whose results have provided an adequate answer to these three questions. The first question can be answered from impact matrixes that have been developed to facilitate decision-making process during periods of drought (WDCC, 1998; Rossi et al., 2005). The answer to the second question can be found in the Drought Management Plans that have been developed for this purpose (Wilhite et al., 2005), while the third can be answered from our knowledge about available water resources, the uses that must be satisfied, the possibilities for saving water, and finally, the flexibility of the system.

The most innovative document is one in which the impact of droughts is assessed by means of matrixes constructed for the three components that lead to sustainable water policy: social, economic and environmental. Not only do we require the necessary resources and time to carry an action out, but must also consider if such an action or

measure can be applied immediately or not; an essential step towards defining whether actions are direct or indirect. At the same, direct actions can be either of a long term (or proactive) nature or short term (or reactive) nature.

GENERAL IDEAS ABOUT ACTIONS

Let us first refer to direct long term or proactive actions. These are actions whose results become evident particularly in the mid and long term. Ultimately, they are actions which will permit water policy to be adapted to the current circumstances. Secondly, there are short term or reactive actions which are implemented during a drought and follow the pace of its evolution. To a large degree their efficacy will depend on the proactive actions that have been implemented in advance. Thirdly, there are the so-called supplementary or indirect actions. This type of action is aimed at facilitating the implementation and development of the other groups of measures (proactive or reactive) with which drought is managed in a direct manner.

Let us take a look at the figure 1 (USACE, 1994), which defines drought from a hydrologic viewpoint. While water availability largely depends on the hydrologic year, consumption follows a more uniform pattern. Although the possibilities of increasing water supply are limited in developed countries, the margin of action concerning consumption is much larger and continues to widen. In any case, proactive measures are understood as any action that either contributes to increasing resources (for example, reutilization) or permits water use to be reduced (for example by improving water network performance). Measures of a proactive nature require time and how and to what degree they should be implemented necessitates discussion and negotiation in times of abundance. We should not forget that, in addition to time, all measures require funding and on many occasions, legal reforms. Periods of drought clearly do not favor the proper state of mind needed to introduce the far-reaching proactive measures.

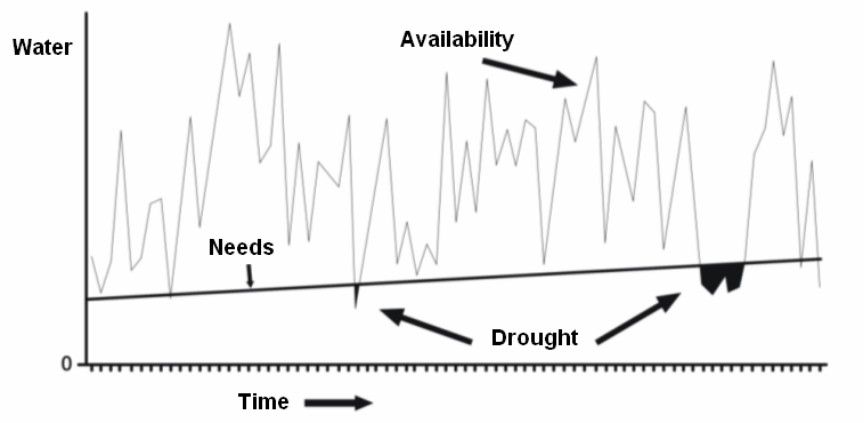

Fig. 1. **Drought from a hydrologic viewpoint**

On the other hand, reactive measures are measures which are implemented to reduce impact when in the throes of a drought. In other words, these are strategies which are taken during periods of scarcity, but which should be negotiated by all of the parties involved when the situation is “normal”. To reduce the impact of water shortage it is useful to previously develop an impact matrix that classifies the consequences of drought and allows decisions to be made in a reasonable manner. One example of an impact matrix for drought management (figure 2) has been developed in detail by the Western Drought Coordination Council (WDCC, 1998).

In short, drought impact decision matrixes are little more than assessment tools that account for a variety of criteria (those in the table are some of the most obvious, but not the only ones) concerning the damage that can be inflicted as a result of restrictions. Based on

the final ranking in the matrix analysis, it is possible to establish how to ration water in the most convenient way from the viewpoint of the general public (Wilhite et al., 2005).

Impact	Cost	Equally Distributed?	Growing?	Public Priority?	Equitable Recovery?	Impact Rank

Fig. 2. **Example of an impact matrix**

It is common to group impacts according to a variety of criteria (economic, environmental and social) that should be envisaged in all sustainable water management plans. The first of these, albeit not necessarily the most important, are the most evident. Thus, for example, the loss of crops or livestock or the costs incurred when water is restricted are perfectly quantifiable. On the other hand, environmental impacts include, among many other consequences, the loss of animal and plant diversity or the disappearance of wetlands and natural springs. Finally, droughts produce numerous social impacts. An example of this type of impact includes the numerous conflicts that arise among users who compete for water in times of drought. A detailed list of such impacts appears in a report by the Western Drought Coordination Council (WDCC, 1998). This report also includes tree diagrams to analyze and follow-up on impacts in terms of the different uses.

Yet of all these criteria, the economic criterion is the most "measurable" (that which is most quantifiable) and obvious of all. It should come as no surprise, then, that researchers and institutions (Jenkins et al., 2003; USACE, 1994) propose methods to analyze the economic losses deriving from water shortages. There is no question that mitigating the economic impact is an essential part of proper drought management.

In fact, measures are considered reactive precisely because of the fact that they are provisional. But their development, discussion and implementation are conditioned not only by the physical and legal framework which encompasses them, but by the serenity that they demand. When the necessary calm is lacking, it is almost impossible to discuss priorities. When restricting consumption, the ranking will be more efficient the more robust the system.

Finally, there is a wide range of actions aimed at minimizing the impact of drought. However, as they do not directly affect the water balance, they should not be considered direct measures. Instead, these are measures that serve to complement direct actions as their ultimate objective is none other than to smooth the way for the latter. Thus, for example, a new economic water policy oriented towards promoting efficiency and therefore giving meaning to a large number of direct actions, indirectly contributes to achieving a balance between resources and uses; an especially difficult balance to reach in times of drought.

DIRECT PROACTIVE ACTIONS

Because these measures are incompatible with improvised actions, they should be implemented in a progressive manner. The principle measures are outlined below according to how they contribute to increasing resources or rationalizing consumption.

Increasing and diversifying supply

- New storage facilities.
- New surface water extractions, generally through transfers between basins.
- Centers for the exchange of water rights.
- Desalination.
- New groundwater extractions.
- Recharging aquifers, a simple and efficient way to conjunctively use surface waters and groundwaters that should be highlighted in an explicit manner.
- Reutilization.
- Optimize resources through better hydrologic planning and monitoring. Make better use of the enormous possibilities that the conjunctive use of surface waters and groundwaters affords, especially in times of drought.

- Finally, it is fundamental to manage a system's resources in preparation for episodes of drought. To do so, it is essential to have an adequate early warning system and drought characterization system as well as using mathematical models that aid in decision-making processes for the management of reservoirs in real time according to the risk of drought (Andreu et al., 1996; Rossi et al., 2005).

Many of these actions require an extended period of implementation, large budgets, political negotiation, social acceptation and when appropriate, modifications to the legislation. This is of foremost importance given that these are works which, in addition to affecting hundred of thousands of people, will be carried out over several terms of office from the time they are conceived until they become operational.

The actions above were ranked beginning with the most difficult (of any kind) to develop and concluding with the easiest to implement. Nevertheless, and as regards their execution, the final decision should, as always, be based on economic, environmental and social criteria. Logically, the work concerning these actions should be oriented towards analyzing the minimum requisites demanded by each of them and from there, assessing their possibilities for development and ultimately, their feasibility. Finally, a comparative analysis of the possibilities afforded by each and every one of the strategies would be of great utility.

Managing demand

This second via began to be explored in detail in the developed world some decades ago and thanks to this new line of study the margin of savings is now quite large. A recent survey (Pacific Institute, PI, 2003), which serves as a point of reflection, estimates the potential savings in urban and residential water use in California (where for some years programs have been set up to foment efficiency) at a minimum of 33%.

While potential savings in urban and residential water use is notable in Spain, it only accounts for a quarter of the demand in the country and in fact, much greater savings can be achieved in irrigation. Indeed, there are clear indications to this effect. When assuming the energy costs for elevation, groundwater irrigation is five times more productive than surface water irrigation in economic terms (Corominas, 2000). In this line, and according to the provisions set out by the Ministry of Agriculture, Fisheries and Foods (MAPA, 2002) in the National Irrigation Plan, more than 5000 hm3 of irrigation water can be saved in Spain through programs to improve water consumption in irrigated areas and reduce excess supply. Indeed, due to the important role of irrigation, numerous studies have been dedicated to optimizing water use in the countryside (Pereira et al. 2002). This knowledge is essential for managing droughts in a rational manner.

These are specific actions that contribute to reducing water demand which on many occasions need to be adapted to the different uses to which water is put (urban, residential, commercial, agricultural and industrial). Among others, these include:

- Measuring all of the uses and resources (including groundwater wells).
- Improving the performance of water transport systems (canals, irrigation channels, transport and distribution pipelines and even installations inside buildings).
- Using rainfall (water harvesting).
- Reutilization of gray waters in homes and industries. Industrial recirculation.

DIRECT REACTIVE ACTIONS

In this second group, we must refer to the decision tree diagram that sets out how to manage a drought according to its evolution based on the established protocol and taking into consideration risk matrixes. These are decision trees or protocols that, in accordance with current legislation and logic, should take into account at least two levels: that of the hydrographic basins and that of the city.

The protocols have to summarize and discuss all of the factors that must be taken into consideration in the event of a drought. They include such issues as the makeup of the teams in charge of developing a drought management plan, how to reconcile conflicting interests, methods of measurement that must be taken into account with a view to making objective decisions as well the negative impact of outdated legislation on drought management.

It is important to highlight that after consulting the vast information that is available on this issue, especially in the United States (drought management plans for thirty different states can be found at http://drought.unl.edu/plan/stateplans.htm/), we have come to the conclusion that the Drought Management Plans developed in any country must follow similar criteria.

In Spain, we are all, in some way or another, following in the wake of the Isabel II Canal, city of Madrid, that has recently updated its plan (Cubillo and Ibáñez, 2003); a plan that is, without a doubt, a first-rate document. But, as I have already said, due to its singular characteristics, the Isabel II Canal is not an example that can be followed by the majority of Spanish cities.

This is not the case of England where the Environment Agency (EA, 2003) has recently published the second revision of the drought management plans developed by water companies in the country. Prior to these plans, the EA had provided clear guidelines for drought management.

Many other urban contingency plans are available on water company websites, especially those which are publicly owned. This is the case for example of Melbourne Water in Australia (MWC, 2001) or Denver Water in the United States (DW, 2004). The Water Conservation Committee of the AWWA (WCC, 2002) has developed a model drought management plan. This plan serves as a support tool for the development of drought plans that will facilitate the work of managers in water companies.

Considering the above, the excellent and thorough work Managing Water for Drought (USACE, 1994) merits particular attention as it is the result of a thorough study carried out by more than one hundred professionals. The study was conducted in the early nineties and it was the administration's reaction to the low rainfall recorded in the western United States at the end of the eighties.

SUPPLEMENTARY OR INDIRECT SUPPORT ACTIONS

Given that the indirect actions do not directly mitigate the effects of drought - even when they lead to the success of direct actions of both reactive and proactive kind - we will considered them separately by structuring them into two different blocks according to the type of direct actions that they influence.

Measures that support proactive actions

These measures facilitate the implementation of complex, but necessary direct proactive actions. Among others, these include:

- Citizen awareness.
- The participation of sociologists and communicators that aid in transmitting the message.
- Media involvement.
- Foster citizen participation.
- Adequate economic policies that foment efficiency and flexibility of use.
- Proactive water policies that monitor both water use and water resources.
- Adapt the legislation to the current context. Revise historical water rights.
- Adaptation of the administration. Water management and monitoring needs to be coordinated.
- Centers for the exchange of water rights.
- Provide technical assistance to towns and irrigation communities

The importance of the first four actions in the above list should be underscored. These are actions that are essential to achieving the viability of the other actions. The remaining actions are those that directly contribute to mitigating the impact of drought. However, it is clear that if we do not prepare the ground beforehand, it will be unfeasible to implement them.

Measures that support reactive actions

A Drought Management Plan resembles a decision tree diagram which, depending on the circumstances, guides planners in one direction or another. Decision-making is a

dynamic process. In short, all of the actions that permit us to remain one step ahead of the problem are included in this section, as well as supplementary actions. Forecasting and characterizing droughts is a research topic that has gone hand in hand with the stochastic analysis of hydrologic series (Yevjevich, 1967; Dracup et al., 1980). Due to the growing impact of water shortages, research continues to be conducted in this line (Salas et al., 2005).

However, in order to manage drought in such a way as to mitigate its impact before a drought occurs, and from the viewpoint of needs that must be satisfied, we must assess the water deficit. The balance between availability and need is the origin of other indicators; indicators which activate the various stages of a Drought Management Plan (Fisher and Palmer, 1997). To sum up, when reliable information is available, it is possible to foresee the events and properly manage reactive actions that have been designed in advance for this purpose.

The remaining strategies and actions either facilitate the development of drought management plans (conflict management) or promote both the acquisition and dissemination of knowledge. All of these actions would therefore include:

- Meteorological accurate follow-up and adequate data treatment.
- Meteorological drought indicators.
- Drought management indicators.
- Activation thresholds for the different phases of a plan.
- Conflict resolution.
- International relations.
- Technical assistance.

CONCLUSIONS

The main conclusion that can be drawn from the above is that a drought cannot be managed efficiently without a plan that has been properly developed beforehand. A plan that takes into account both proactive and reactive measures will permit exceptional measures to be reduced to a minimum; measures which until now have been applied in a systematic manner (curiously, exceptional is an antonym of systematic) and characterize the actions implemented by water administrations in many countries in times of drought. Thus, the final goal is to ensure that planning, rather than improvisation, prevails in the event of a drought.

The economic, social and environmental impacts caused by the increasingly frequent water shortages occurring in the 21st century will continue to worsen. Although it has not been mentioned explicitly in this report, we should not forget the looming threat of climate change, making rational drought management of vital importance to the future. To achieve such an aim, however, we must travel down a very long road that should not demoralize those who walk upon it.

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